PATHWAY IDENTIFICATION DURING SUCCESSFUL ISCR-ENHANCED BIOREMEDIATION OF A TCE DNAPL SOURCE AREA

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TOPICS

- Site Overview
- Bench Test
- Field Pilot
- Full-Scale Data
- Summary

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Site Overview

- Former MGP waste site redeveloped for manufacturing in 1970s
- 80+ acres adjacent to Portland Harbor NPL site
- TCE or TCE+wastewater released from a recycling system (1980-1985)
- Impacts from release discovered in 2002

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Site Overview

- Source Zone
  - Impacts from about 15-34 m bgs
  - TCE up to 592,000 ug/L (DNAPL levels)
    - No TCE DNAPL observed
  - Cis-1,2-DCE up to 90,800 ug/L
  - Very little VC (< 100 ug/L)
- Riverbank
  - Impacts from about 24-43 m bgs
  - TCE up to 8,640 ug/L
  - Cis-1,2-DCE up to 34,000 ug/L
  - VC up to 5,170 ug/L

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Site Overview

Bench and Pilot Test Summary

- Comparative Bench Test
  - Multiple columns and runs, TCE spikes up to 870 mg/L
  - EHC+KB-1 outperformed other amendments
    - EHC – ZVI+hydrophilic organic carbon
    - KB-1 – *Dhc* consortium
- Source Area Pilot – EHC+KB-1 PRB
  - TCE from DNAPL levels (93 mg/L) to ND in 6 months
- Riverbank Pilot – EHC+KB-1 PRB
  - All CVOCs to ND in ~12 months

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Technology Summary

- EHC
  - Powdered blend of zero-valent iron (ZVI) and hydrophilic organic carbon
  - Creates strongly reducing conditions in groundwater (ORP ~ -500 mV) – *in situ* chemical reduction (ISCR)
  - ISCR results in abiotic dechlorination and supports anaerobic bacteria
- KB-1
  - Anaerobic consortium of dechlorinating bacteria
  - Includes *dehalococcoides* sp.
  - Requires ORP < -75 mV

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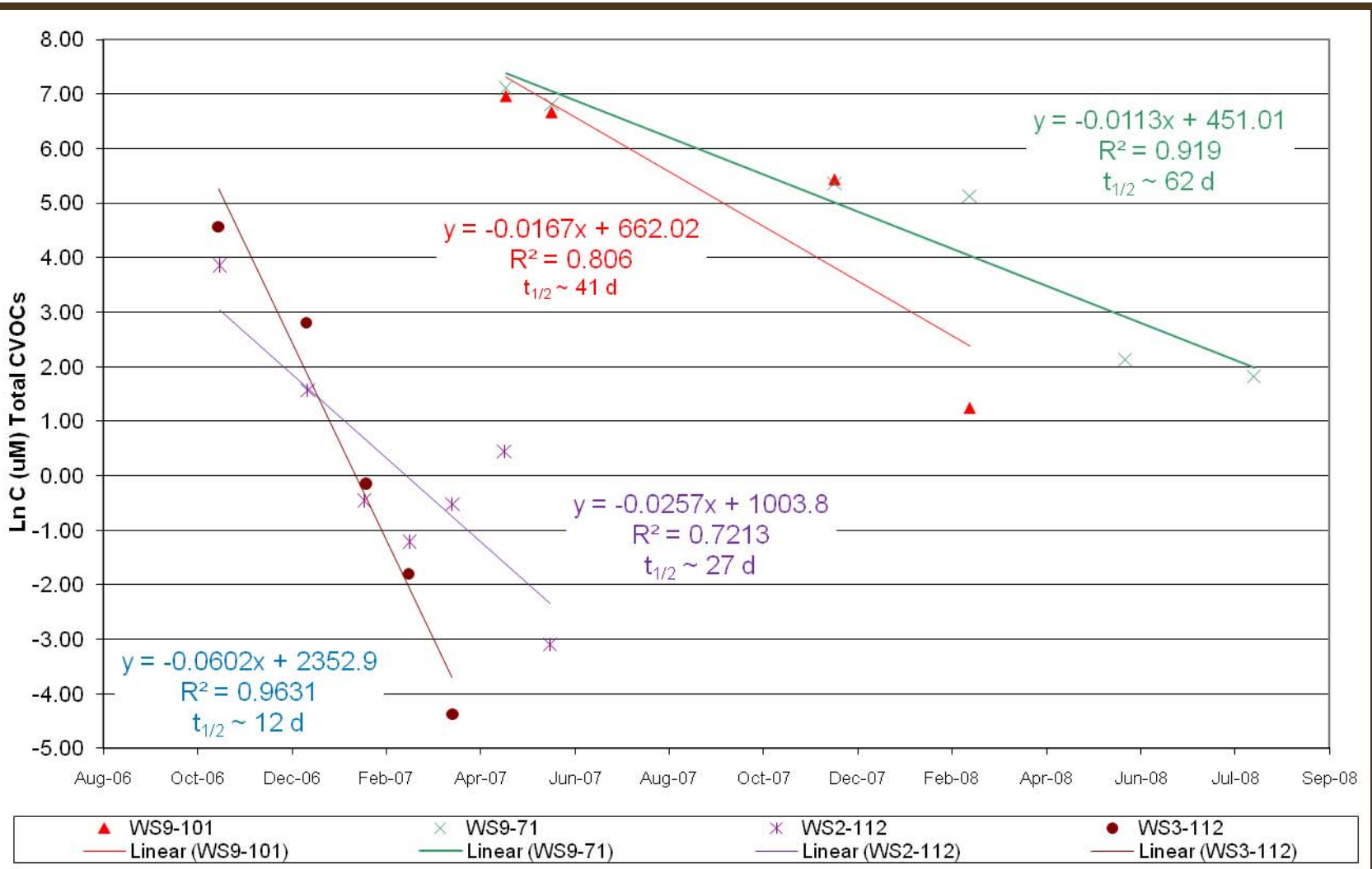
Field Pilot Data – CVOC rates



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Full Scale

- EHC+KB-1 Full-Scale Implementation
  - 46 m x 21 m x 3 m PRB – Source area only
    - Injected from ~12 – 34 m bgs
    - Supplemental upgradient areas
  - 200+ injection points
    - ~269,400 kg EHC
    - 1,831 L KB-1
  - Direct-push drilling
- 23 Performance Monitoring Wells
  - Group 1 – Upgradient or within injection zone
  - Group 2 – Downgradient of injection zone

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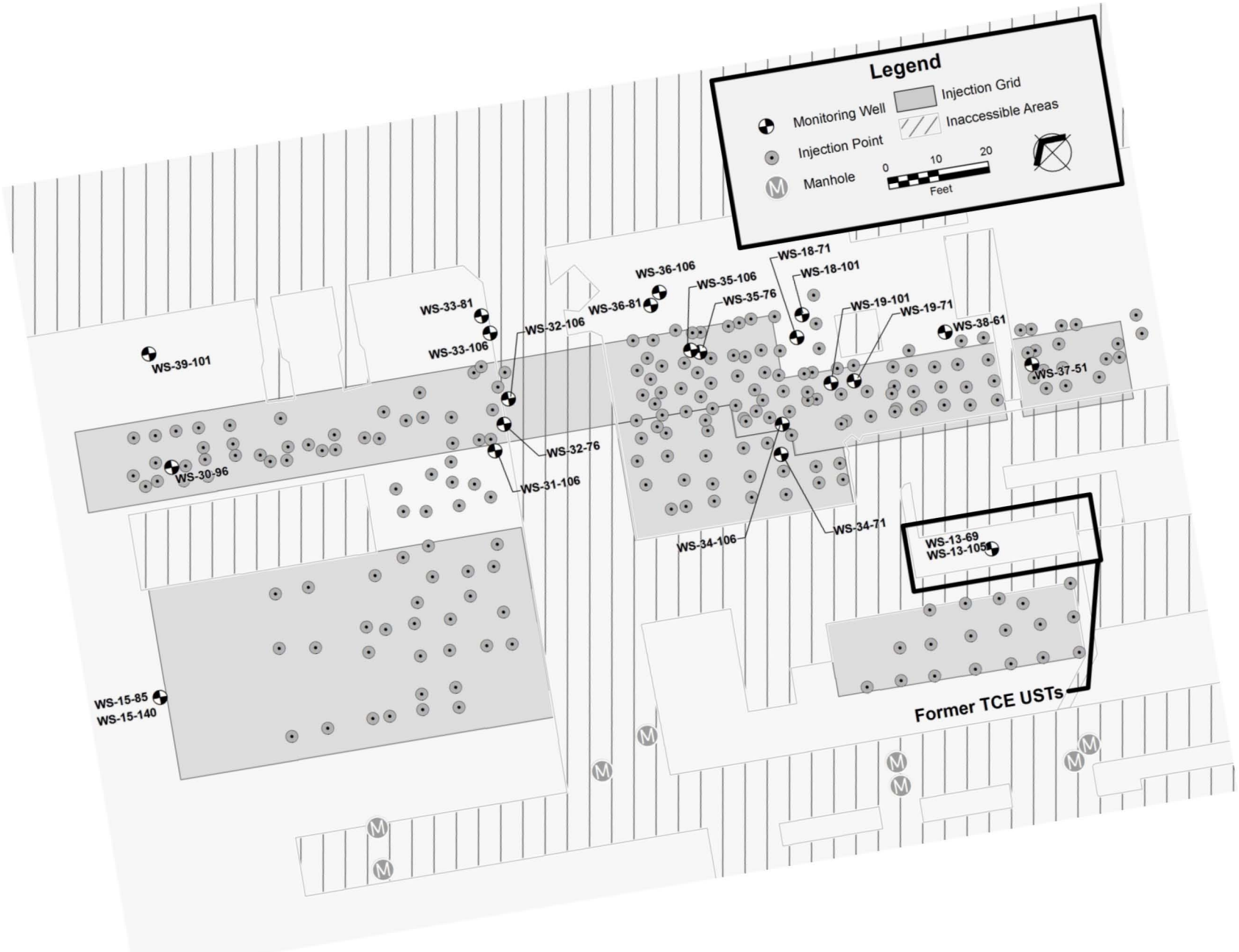
Full Scale


Legend
Monitoring Well
Injection Point
Manhole
Injection Grid
Inaccessible Areas
0
10
20
Feet
WS-39-101
WS-33-81
WS-33-106
WS-32-106
WS-36-81
WS-36-106
WS-35-106
WS-35-76
WS-18-71
WS-18-101
WS-19-101
WS-19-71
WS-38-61
WS-37-51
WS-30-96
WS-32-76
WS-31-106
WS-34-106
WS-34-71
WS-13-69
WS-13-105
WS-15-85
WS-15-140
Former TCE USTs

TCE Results (ug/L)

Well ID	Group ID	Pre-Injection (Q4-08/Q1-09)	December 2009	February 2010	April 2010	June 2010	August 2010
W13-69	1	174,000	6,050	4,400	9,510	10,100	1,570
W30-96	1	80,900	90.7	83.2	22.2	21.3	18.9
W31-106	1	23,800	1.57	***<0.3***	***<0.3***	0.35	***<0.3***
W32-106	1	17,400	30.5	9.45	5.92	6.51	3.23
W32-76	1	44,500	51.6	52.1	66.9	43.2	7.3
W35-106	1	157,000	14.9	8.84	3.99	6.61	5.43
W33-81	2	21,400	92.2	160	64.8	24.4	20
W36-81	2	13,800	22.7	18.1	10.2	7.78	1.87
W39-101	2	120,000	7,800	7,780	4.88	6.31	4.37
	Mean	72,533	1,573	1,390	1,077	1,135	181

- Subset of wells with pre-injection TCE > 11,000 ug/L

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Results

- Remedial action objective is 11,000 ug/L
  - Threshold indicator for TCE DNAPL
  - 1 % of aqueous solubility limit
  - Achieved in less than 12 months
- TCE generally less than 100 ug/L
- Estimated 99.9% mass removal

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Pathway Identification

- Mix of abiotic and biological pathways
- Evidence of abiotic degradation
  - Simultaneous decline of TCE/DCE/VC in some wells
  - Abiotic degradation products
    - Hydrogenation of chlorethenes to chloroethanes
    - Low concentrations but consistent
- Clear evidence of sequential dechlorination
  - Production of DCE isomers and VC

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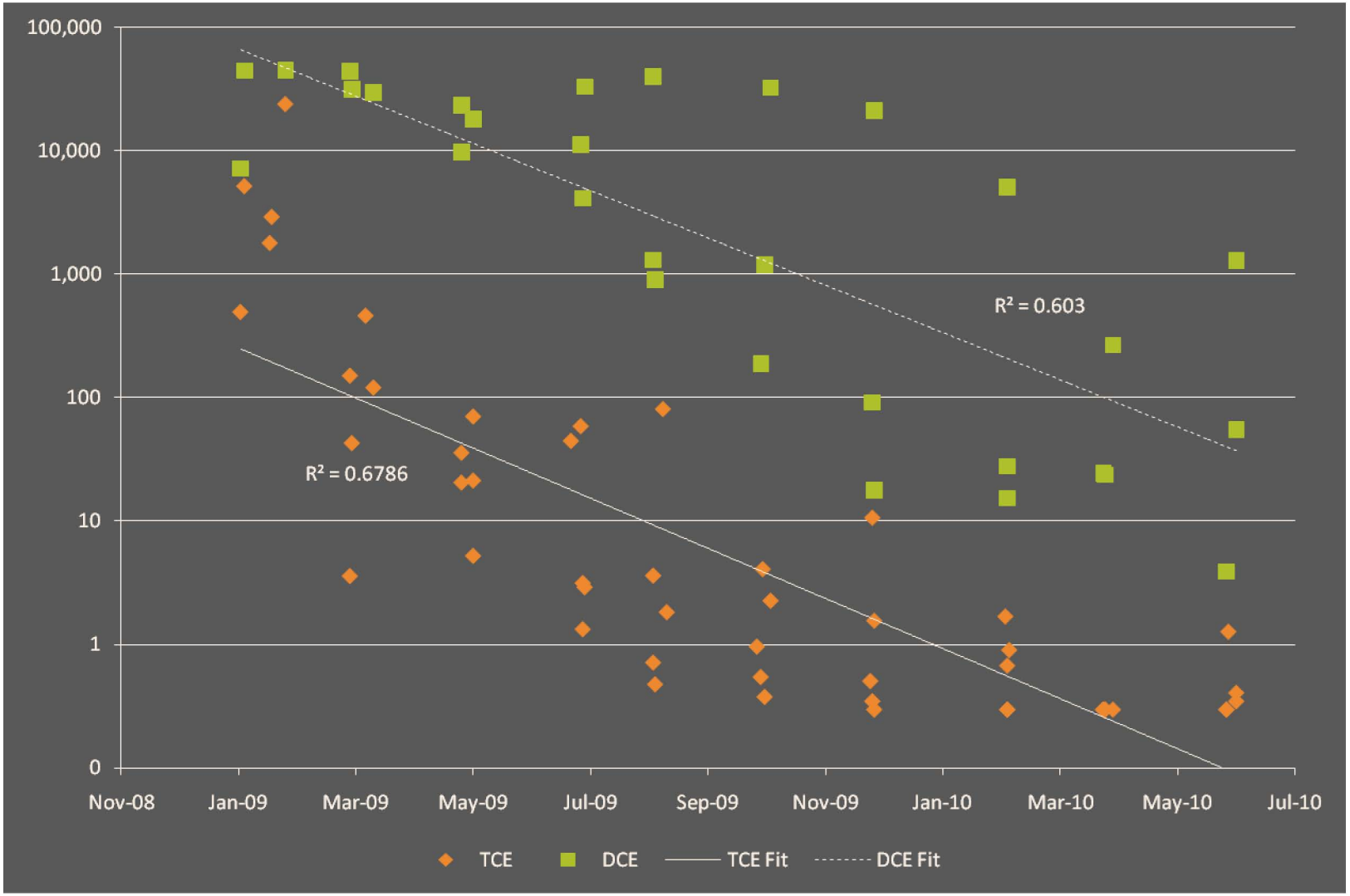
Pathway Identification - Abiotic



TCE DNAPL Remediation

- No TCE DNAPL observed
  - Elevated groundwater concentrations
  - 592,000 ug/L (direct-push)
  - 259,000 ug/L (monitoring well)
- Indirect evidence of TCE DNAPL
  - Mass balance using chloride?
- Evaluate entire source area data set
  - EVS estimates of 3-D source area volume

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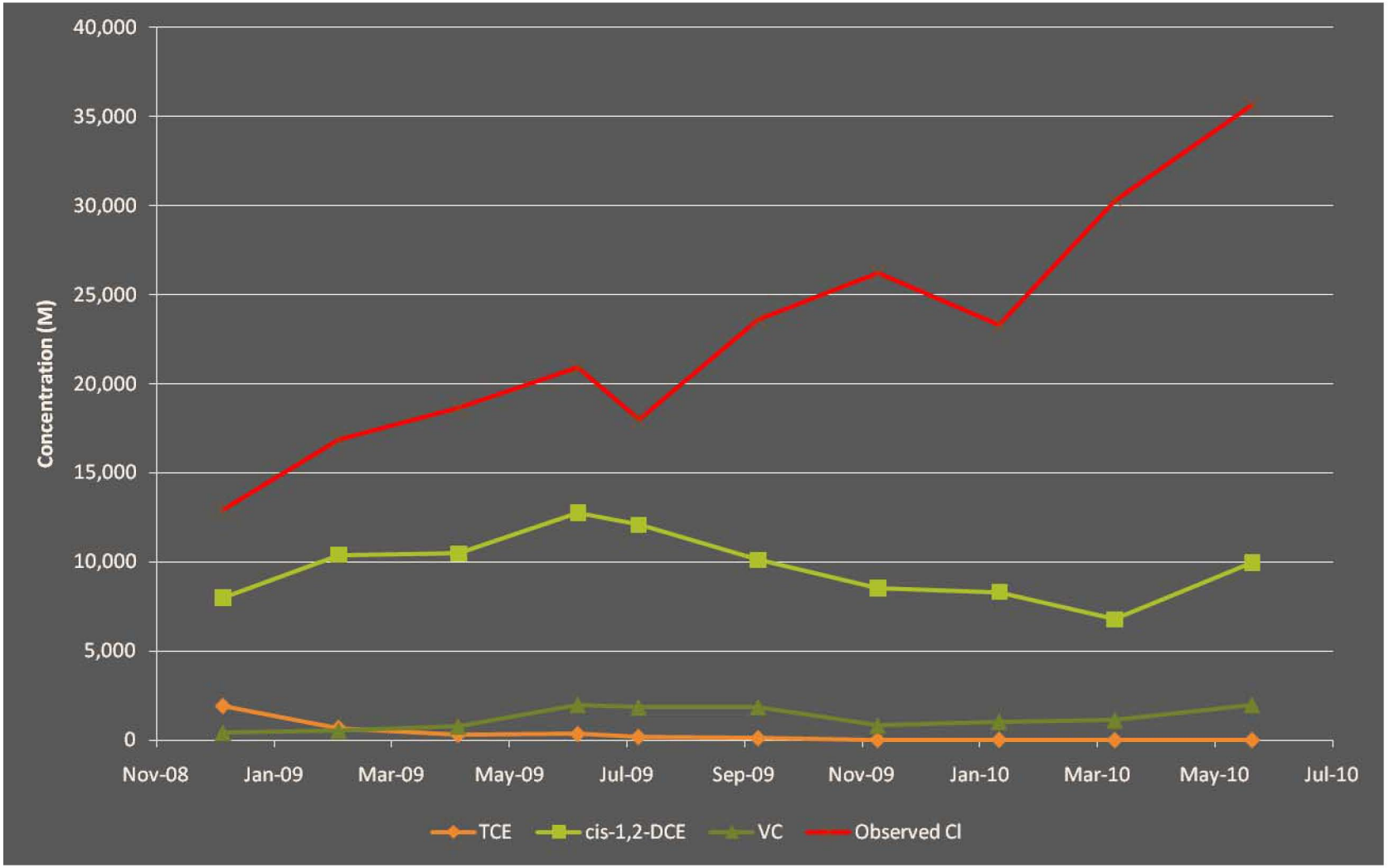
TCE DNAPL Remediation



TCE DNAPL Remediation

Observed Net Increase in Cl (*M*)	22,498
Net Theoretical Cl from Degradation of CVOCs (*M*)	9,073
Difference (*M*)	13,425
TCE Equivalents (*M*)	4,475

- Mass balance example
  - Convert molar TCE/DCE/VC to molar chloride
  - Compare theoretical total Cl (*M*) to observed
  - Difference implies degradation of TCE DNAPL
    - Includes degradation of desorbed TCE
  - Action implies accelerated desorption from non-aqueous phases(s) to aqueous phase

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Summary

- Combined EHC+KB-1 is a demonstrated technology for TCE DNAPL
  - Abiotic and biological pathways identified
  - Both pathways demonstrated success
- Mass balance approach useful for identifying DNAPL degradation
  - Cl data suggest TCE (or TCE equivalents) in non-aqueous phase or phases
- Removal mechanism
  - Accelerated desorption from NA phase
  - Destruction in aqueous phase

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Acknowledgements

- Adventus Americas Inc.
- SiRem Laboratories

- Questions?

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